Silicone based HTF in parabolic trough applications – from lab to loop

2018 10 03, SolarPACES

Erich Schaffer, Wacker Chemie AG

Content

- **Introduction Wacker Chemie AG**
- HELISOL® 5A: chemical and physical parameters
- HELISOL® 5A: operational safety
- HELISOL® 5A: USP´s & Proof of Concept

WACKER at a Glance

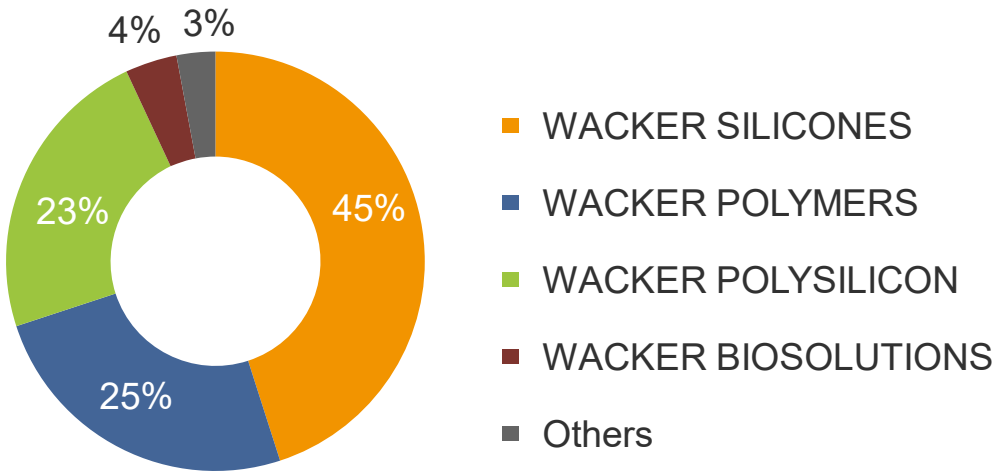
Wacker Chemie AG

- Founded in 1914 by Dr. Alexander Wacker
- Headquartered in Munich

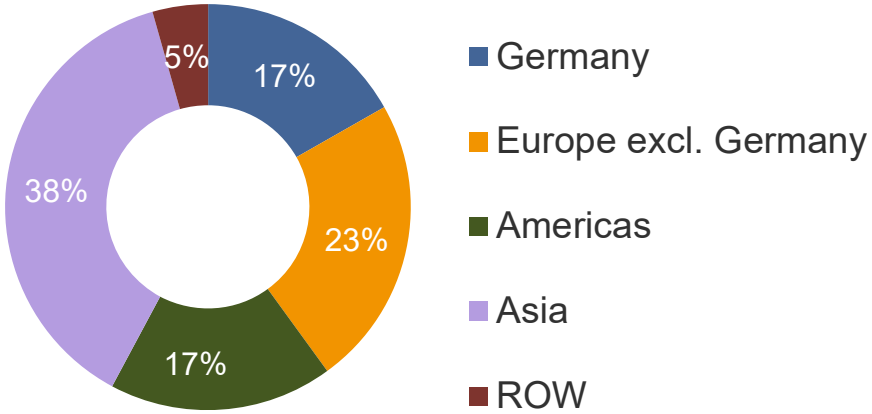
WACKER Group (2017)

- Sales: €4.92 billion
- EBITDA: €1,01 million
- R&D: €153 million
- Investments: €327 million
- Employees: 13,811

Sales 2017: €4.92 bn



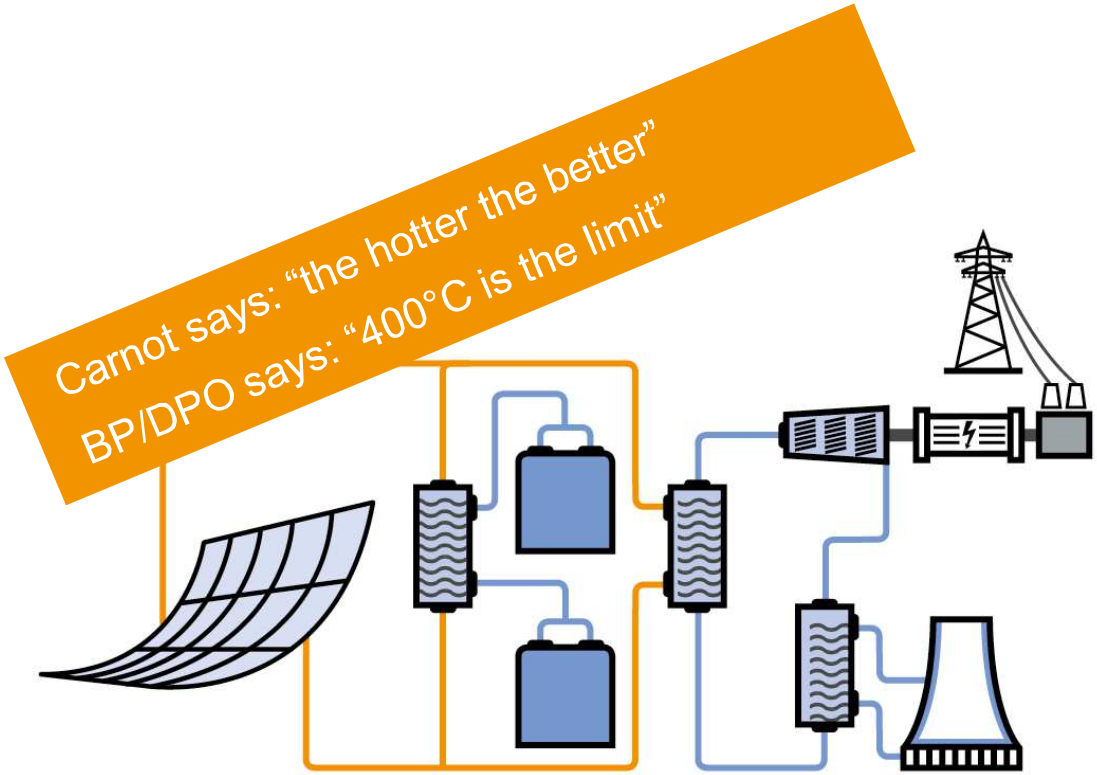
60% of Sales Outside Europe



Content

- Introduction Wacker Chemie AG
- **HELISOL® 5A: chemical and physical parameters**
- HELISOL® 5A: operational safety
- HELISOL® 5A: USP´s & Proof of Concept

New HTF needed to break the 400°C temperature barrier



Benchmark HTF

- Biphenyl-Diphenyloxide (BP/DPO)
- Max. process temp.: 400°C
- Freeze point: 12°C

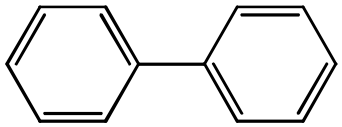
HTF requirements

- High thermal stability
- Good heat transfer
- Low freeze point
- Low vapor pressure
- No critical degradation products
- Low fire risk
- Low cost

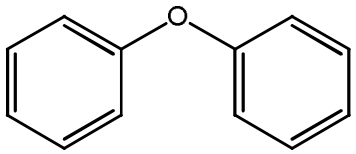
HELISOL® 5A shows advantages over BP/DPO

BP/DPO*

- 25 - 28% BP, 72 - 75% DPO
  (Diphyl® , Dowtherm® A, Therminol® VP-1)



Biphenyl; Diphenyl



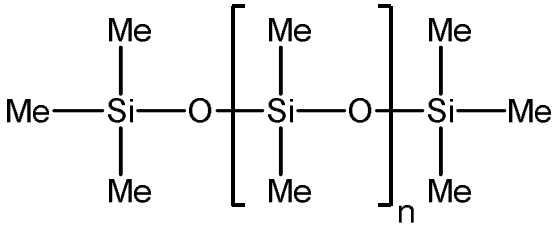
Diphenylether

- Working temp.: 60°C bis 395°C
- Freezing point: 12ºC
- Vapor pressure (400 °C): 11 bar
- Self ignition temp.: 599°C

*BP/DPO (Biphenyl/Diphenyloxid)

HELISOL® 5A

- Low viscosity polydimethylsiloxane,
- Multi-component mixture of molecules



- Working temp.: −40°C to 425°C
- Pour Point: −65ºC
- No freeze protection
- Vapor pressure (400 °C): 16 bar
- Self ignition temp.: 367°C
- Lower H_2-formation
- No Fouling

HELISOL® development - from Lab to Loop

2011	2012	2013	2014	2015	2016	2017	2018	2019	2020

Pre-Assessment

HELISOL® 5A

- higher thermal stability
- no freezing
- lower hydrogen formation

Lab-Scale (TRL* 4)

multigram scale

aging kinetics (autoclave + oven)

degradation / compatibility

*TRL = technology readiness level

HELISOL® development - from Lab to Loop

2011	2012	2013	2014	2015	2016	2017	2018	2019	2020

Pre-Assessment

Si-HTF (BMWI)

HELISOL® 5A

- higher thermal stability
- no freezing
- lower hydrogen formation

Technical-Scale (TRL 5)

HTF volume 0.5 m^3

operation parameters:

- 300°C, 15 bar

*TRL = technology readiness level

HELISOL® development - from Lab to Loop

2011	2012	2013	2014	2015	2016	2017	2018	2019	2020

Pre-Assessment → **Si-HTF** (BMWI) → **SITEF** (SolarEra.NET)

HELISOL® 5A

- higher thermal stability
- no freezing
- lower hydrogen formation

Loop-Scale (TRL 7)

HTF volume 8 m^3

Proof of Concept

- 1200 h solar
- up to 450°C, 23 bar

*TRL = technology readiness level

HELISOL® development - from Lab to Loop

2011	2012	2013	2014	2015	2016	2017	2018	2019	2020

Pre-Assessment	Si-HTF (BMWI)	SITEF (SolarEra.NET)	SIMON (SolarEra.NET)	continuation

HELISOL® 5A

- higher thermal stability
- no freezing
- lower hydrogen formation

HELISOL® XA

- lower vapor pressure
- useable for existing plants

Loop-Scale (TRL 7)

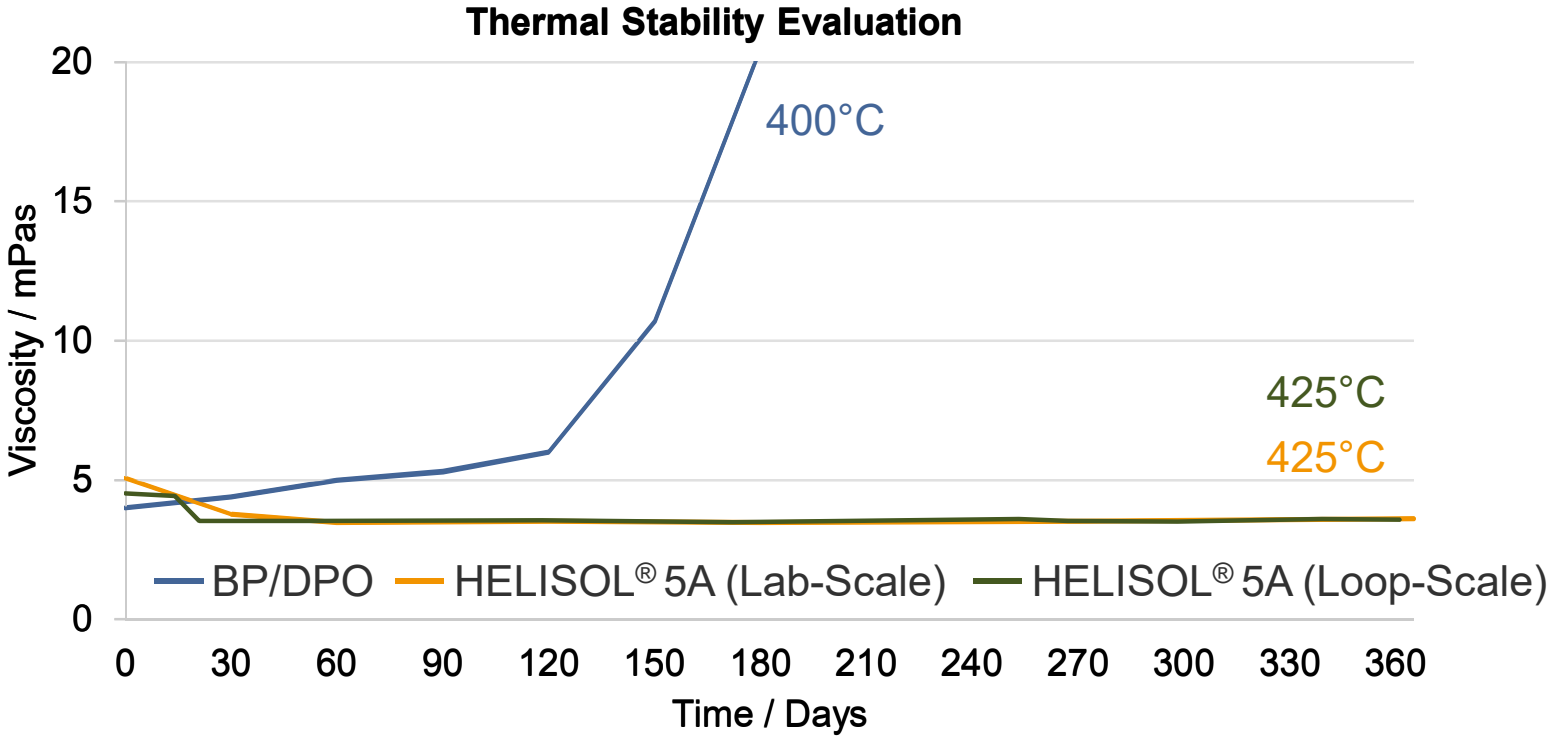
HTF volume 8 m^3

Proof of Concept

- 1200 h solar
- up to 450°C, 23 bar

*TRL = technology readiness level

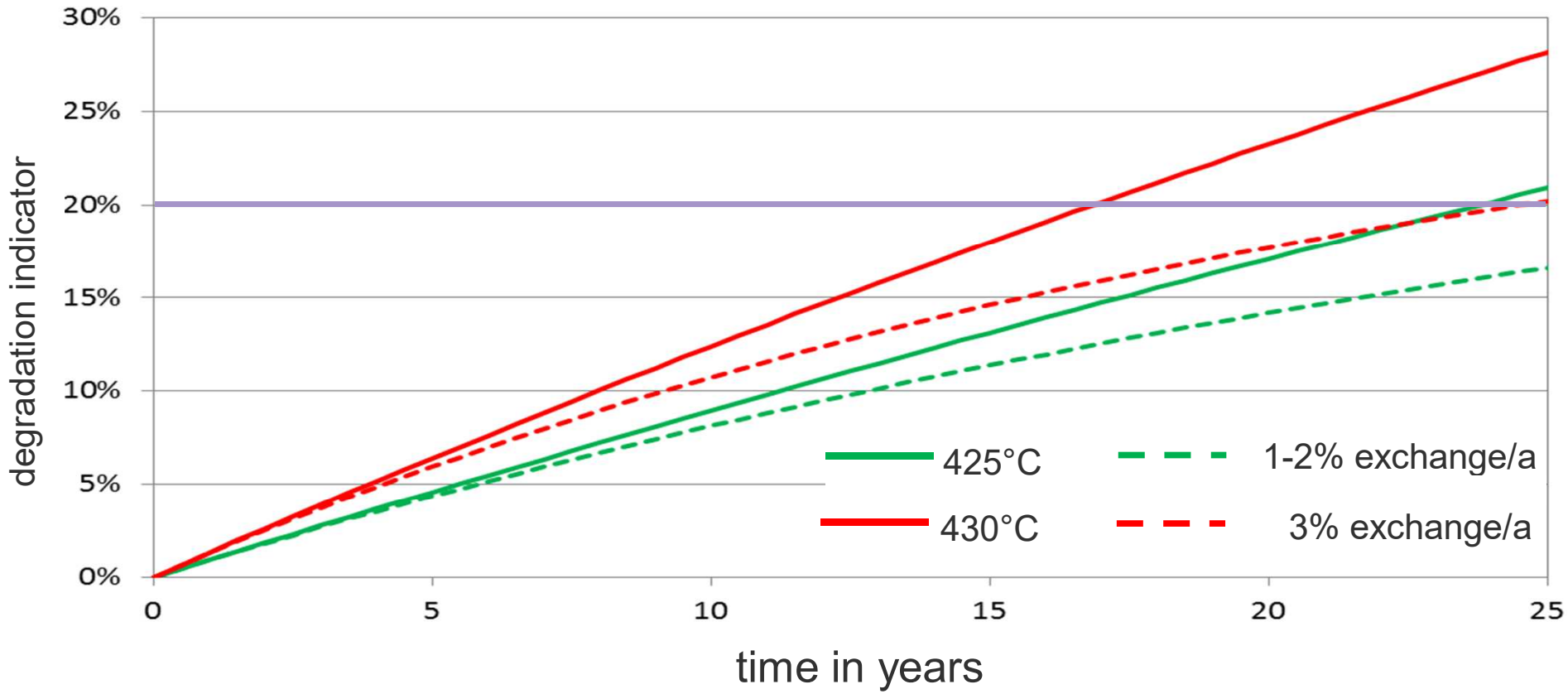
Lab-Scale Thermal Stability Evaluation



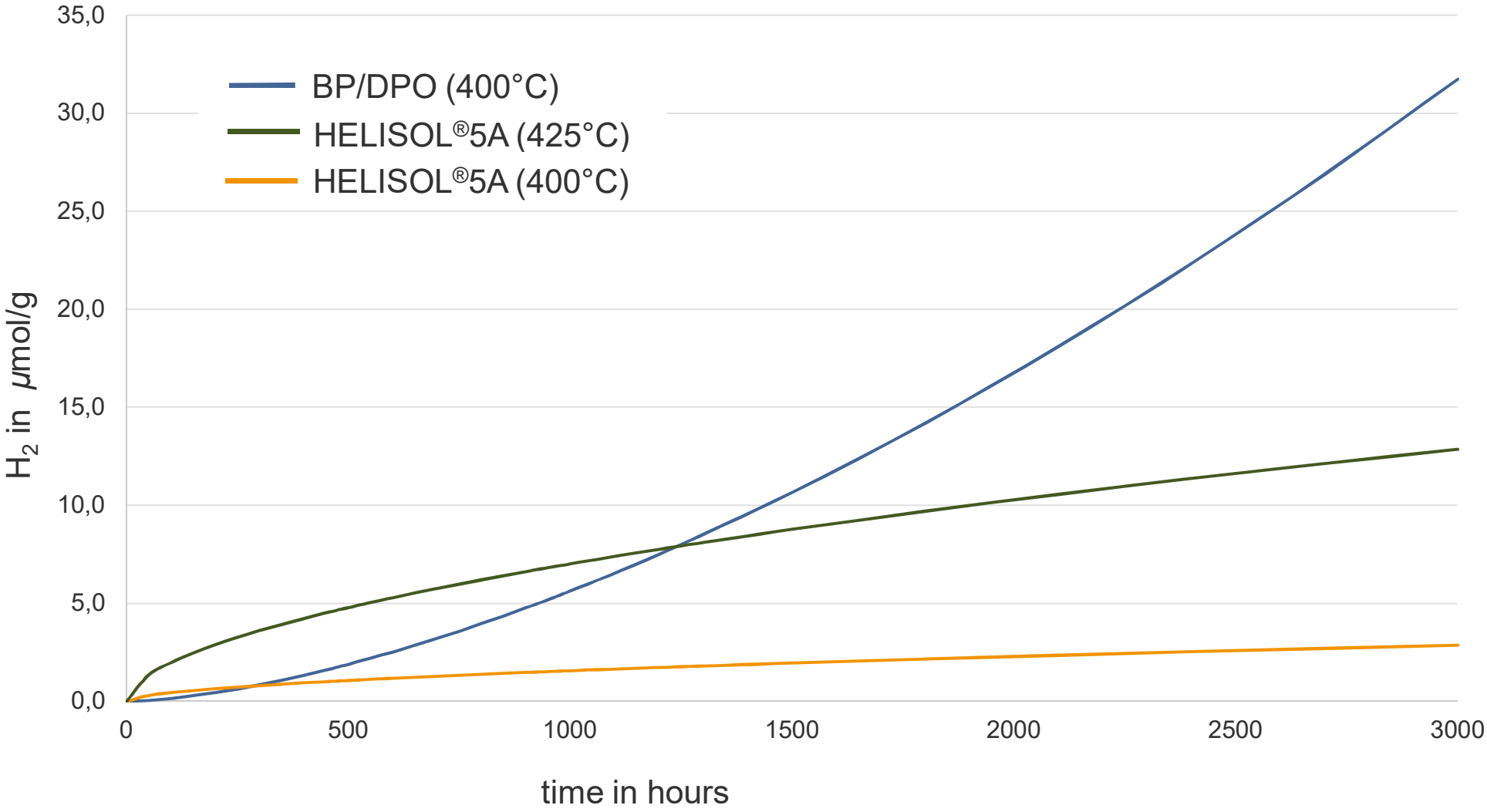
- lab-scale degradation and life-time analysis
- confirmation of data values at loop-scale

  (test facilities in China / Spain)

What is the temperature limit of HELISOL® 5A?



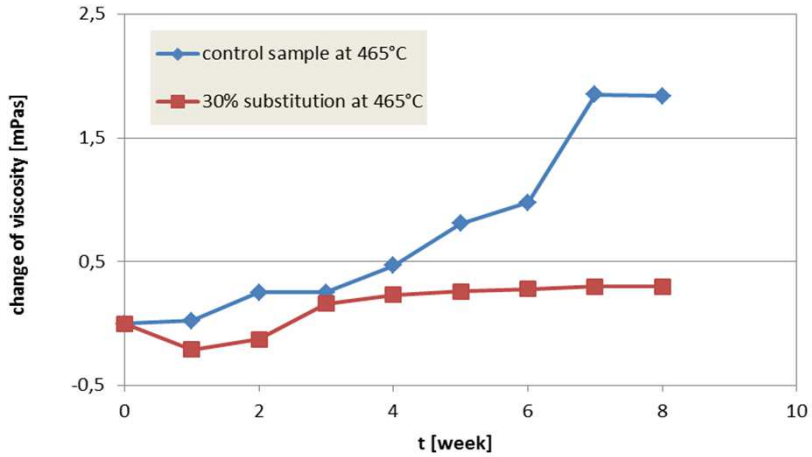
HELISOL® 5A offers a lower long term hydrogen formation



HTF reworking- and gas separation concept easy to apply

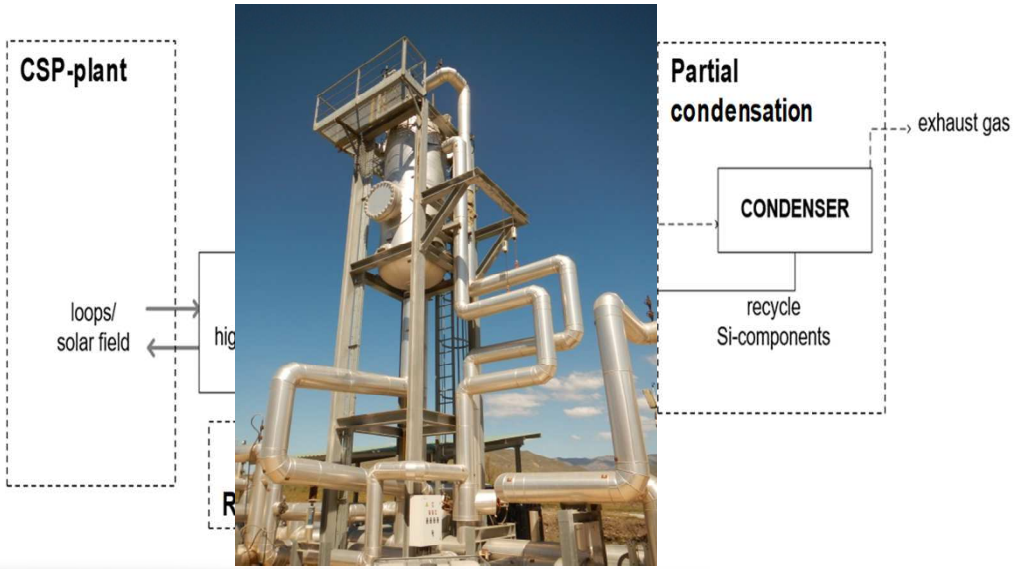
Reworking Concept

- Viscosity is kept constant via HTF exchange
- No Ullage system needed



Gas Separation Concept

- Degradation products:
  H_2, CH_4, C_2H_6, Silane
- Flashing → partial condensation → refeed



Content

- Introduction Wacker Chemie AG
- HELISOL® 5A: chemical and physical parameters
- **HELISOL® 5A: operational safety**
- HELISOL® 5A: USP´s & Proof of Concept

Spray Ignition tests with aged HTF (TÜV) shows no disadvantage of HELISOL® 5A

- BP/DPO: fire at 2-3m distance
- HELISOL® 5A: fire at 1m distance

Spray ignition test: ISO 15029

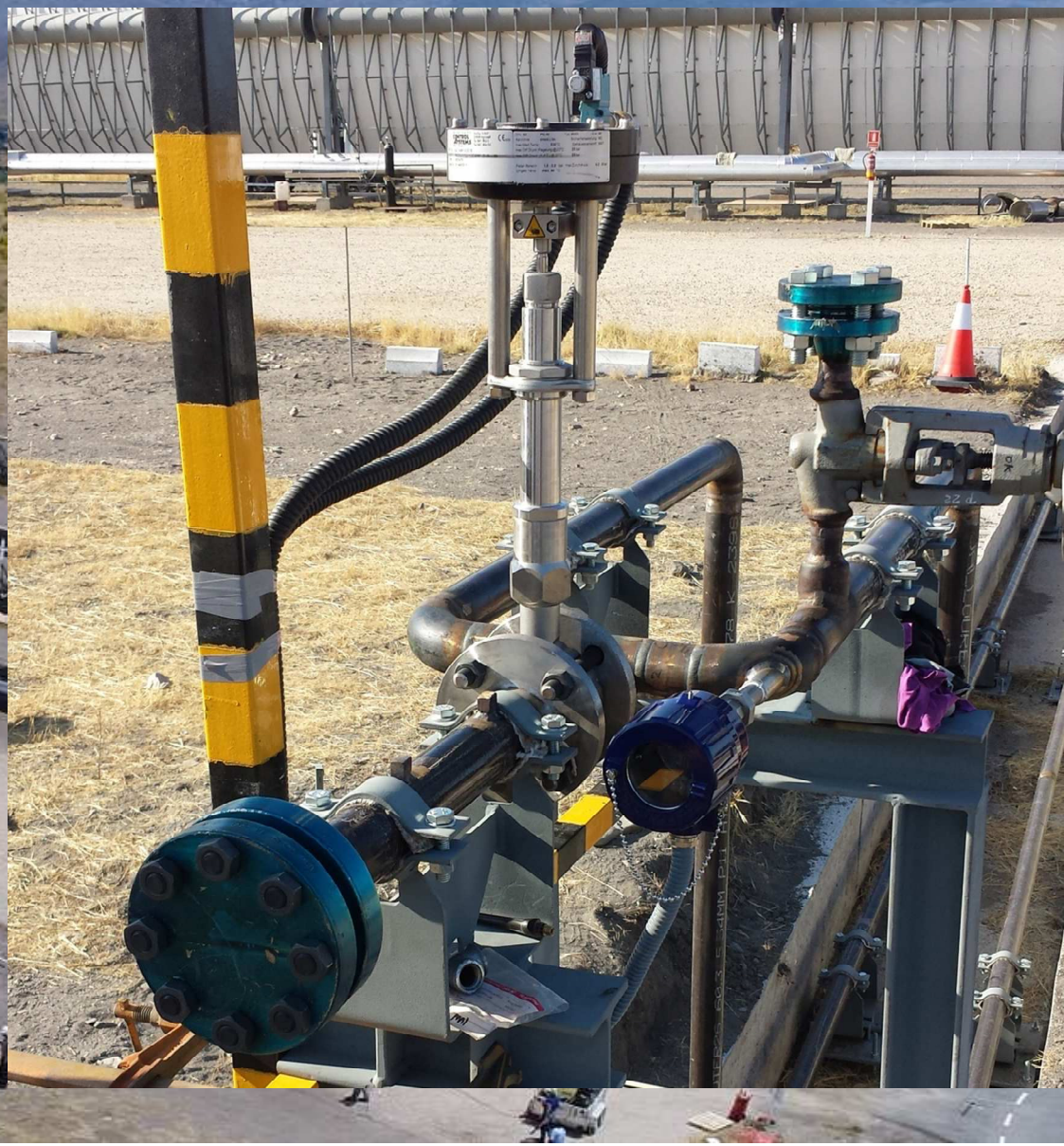
No self ignition of HELISOL® 5A at small scale Release Tests

- 1/4” – 430 °C 15 bar -> **No self-ignition**

Full Scale Release Test (at PSA)

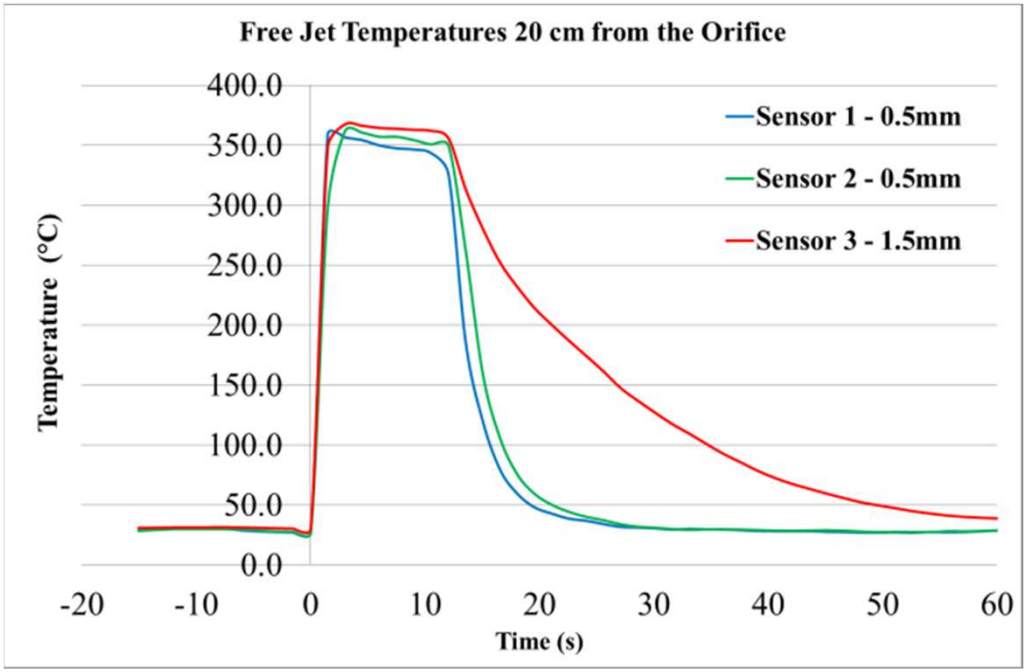
Setup

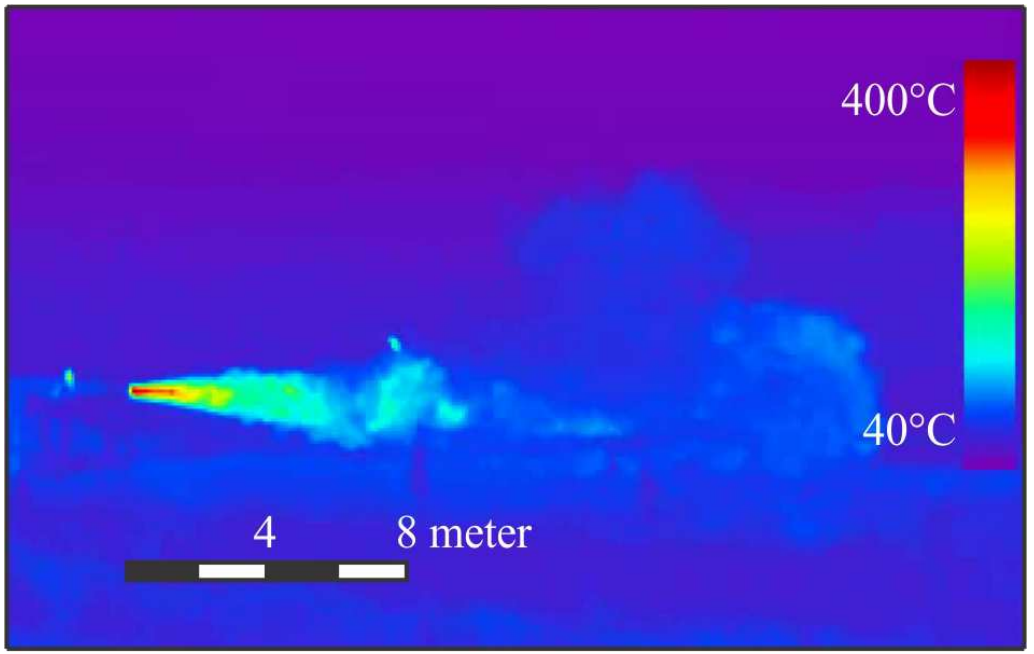
- Fast opening / closing release valve (0.2 sec)
- Different nozzles: ¼“, 1“, 2“



2“ release test performed in May 2018 at the PSA

Full Scale Release Test - Temperature Contribution





IR Camera

Content

- Introduction Wacker Chemie AG
- HELISOL® 5A: chemical and physical parameters
- HELISOL® 5A: operational safety
- **HELISOL® 5A: USP´s & Proof of Concept**

HELISOL® 5A: Up to 5 % LCOE* Reduction Potential

$$\mathrm{LCOE} = \frac{\mathrm{CRF}^{**} * \sum \mathrm{CAPEX} + \sum \frac{\mathrm{OPEX}}{\mathrm{Year}}}{\frac{\mathrm{Revenue}}{\mathrm{Year}}}$$

Revenue (electricity sold)

+ Working temperature: - 40°C to 425 °C

CAPEX

+ Reduced TES*** cost
+ No freeze protection
+ Filling at any time (temperature independent)
+ No Ullage needed for viscosity control
- Higher vapor pressure to be considered

OPEX

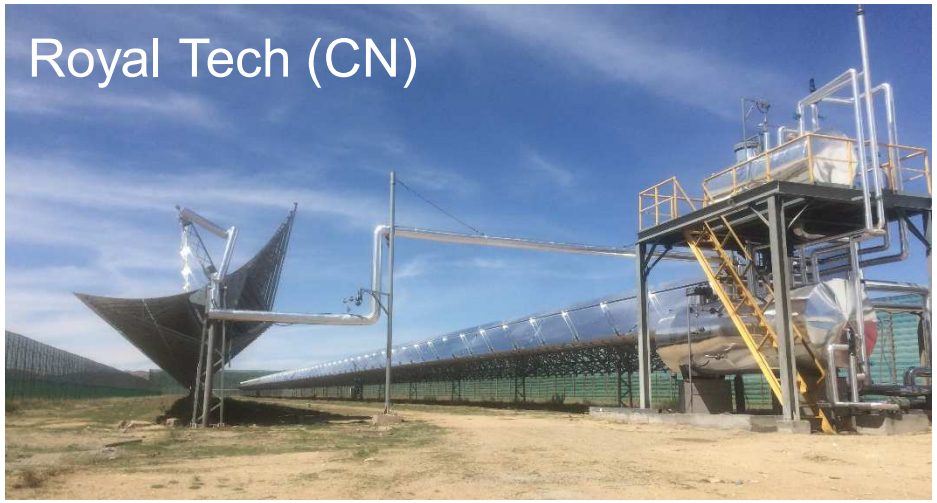
+ No recirculation for freeze protection
+ Maintenance at any time
+ Less pump energy (low viscosity)
+ Shorter start up period
+ Lower degradation/exchange rate at same temperature
+ Lower H_2 generation
+ No fouling

*LCOE: Levelized cost of electricity, **CRF: Capital recovery factor, ***TES: Thermal Energy Storage

Proof of Concept for HELISOL® 5A at independent Demo-Loops

PSA: (2016-2019)

- ~1300h solar operation
- Proof of Concept at 425°C / 520h
- overheating: 435°C to 450°C / 50h



by courtesy of Royal Tech

Inner Mongolia (CN): Royal Tech Demo-Loop

- Operating at 425°C since April 2016
  - ~1800h above 400°C
  - ~850h between 400°C to 430°C
  - overheating up to 470°C
- 50 MW YUMEN (China) project to be realized with HELISOL® 5A

Summing up

- HELISOL® 5A offers extremely broad operating temperature range
- Up to 5 % LCOE reduction potential
- Proof of Concept done - HELISOL® 5A is used already as HTF
- Strategic partnership agreement with Royal Tech (CN) for 50MW YUMEN project

With HELISOL® 5A it is possible to realize a parabolic trough plant with a working temperature above 400°C

The authors would like to thank the German Federal Ministry of Economic Affairs and Energy for the funding of the projects Si-HTF, SITEF and SIMON and their cooperation partners

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag